

Assessment by Francisco Chavez, member Ecosystem Panel

From 1980 to the present depleted dolphin populations from the eastern tropical North Pacific (ETNP) have remained stable or increased much slower than would be expected based on tuna fishery mortality estimates. The question posed was could the environment during this period have been different from previous decades. And then if so was it more or less favorable for dolphin populations. Based on available information I conclude that the environment from about 1950 to about 1975 was considerably different than the environment from about 1975 to about 1998. With much less certainty can I conclude on the magnitude of the change in the ETNP or even if the conditions in the more recent decades were more or less favorable to the dolphins. Below I detail my logic.

There are two prominent modes of variability in the Pacific Ocean that have significant documented influences on biological populations. The first is El Niño that occurs every 3 to 7 years with varying intensity. The climate and biological effects of El Niño have been widely documented (Barber and Chavez, 1983). The second mode of variability has a period of 40-60 years. The spatial distribution of sea surface temperature anomalies associated with this variability looks remarkably like El Niño and its counterpart La Niña (Figure). This 40-60 year variability was first evident in landings of sardines from Japan, California and Peru-Chile (Kawasaki, 1983). Sardine populations flourish for 20-30 years and then practically disappear for similar periods. The periods of low sardine abundance are marked by dramatic increases in anchovy populations. This variability is most notable in the Pacific but extends into the Atlantic where the anchovy and sardine show inverse responses. Several important conclusions can be drawn from this: 1) the variability is difficult to explain based on fishery effects, 2) the mechanism responsible for the variability must be similar in all cases and, some argue relatively simple and direct (Bakun, 2001) and 3) the variability must be associated with large-scale climatic forcing. A further interesting aspect is that the discovery of these so-called biological regime shifts preceded the description of the physical variability. A decade or more after the discovery of the synchronous variations in sardine landings scientists were drawn to fluctuations in the atmosphere and ocean that were remarkably similar in phase and duration to the biological time series (Mantua et. al 1997; Klyashtorin, 2001). Scientists have gone as far as concluding that a climate shift may be best determined by monitoring organisms rather than climate (Hare and Mantua, 2000). Recent theoretical work supports this conclusion in that complex interleaving of food webs can result in significant biological changes in response to subtle external physical forcing.

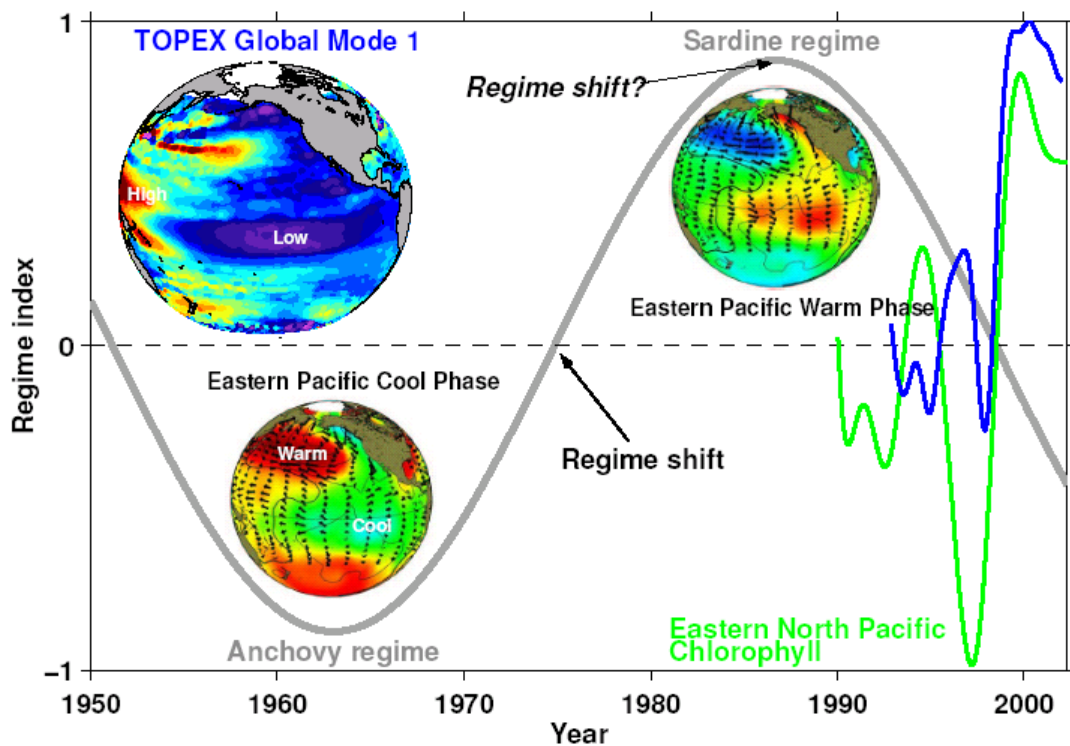
Two of the areas that demonstrate these fluctuations in small pelagics, California (including Baja California) and Peru, are immediately to the north and south of the habitat of the depleted dolphin populations in the ETNP. The dolphin habitat is also adjacent to the equatorial upwelling region and the North Pacific subtropical gyre. Recent evidence suggests that the equatorial Pacific is also subject to longer term fluctuations in upwelling, on time scales that similar to the anchovy/sardine fluctuations (McPhaden and Zhang, 2002). Equatorial upwelling drives the meridional overturning circulation and this circulation has been slowing since the 1970s. The extent of the slowdown and upwelling reduction has been on the order of 25% per decade. During the anchovy regime prior to

1975 a faster subtropical gyre causes the thermocline and nutricline to deepen in the gyre decreasing nutrient supply and productivity. The opposite is true for a slower gyre predicted for the sardine regime that began in the mid 1970s. Indeed, Karl and co-workers (2001) suggest that phytoplankton biomass and primary productivity in the north Pacific subtropical gyre was significantly lower before the mid 1970s than it was measured during the Hawaii Ocean Time-series (HOT) program that began in the late 1980's. They also suggest a shift in community structure with increases in cyanobacteria, *Prochlorococcus* in particular. Given that areas that have demonstrated impact by El Niño and 40-60 year variability surround the dolphin habitat, it seems reasonable that the dolphin habitat should be similarly and possibly significantly impacted.

How would the ETNP change between the 1950-1975 regime and the 1975-1998 regime? The data show that the eastern Pacific was generally warmer during the later (1975-1998) decades than it was prior to that. We can therefore gain some insight on ENTTP by looking at El Niño effects as well as to the available information we have on the regimes. During the warm periods the major currents generally slow and the thermocline deepens. The deepening would be especially pronounced along the thermocline ridge along 10°N. The effect would be to lower nutrient flux into the euphotic zone and reduce primary productivity. It seems reasonable to assume that the effect would cascade through the food chain. Indeed the data collected by NOAA Fisheries scientists seems to show significant changes in dolphin prey abundance associated with El Niño. These abundances increase steadily for several years after an El Niño event. However, one can also similarly think of positive effects associated with the warm phase. Probably the most significant would be that the region becomes more oxygenated. The largest region of ocean with low oxygen and high denitrification rates is the eastern tropical North Pacific (ETNP), with a volume of  $1.4 \times 10^6 \text{ km}^3$ , supporting ~34-45% of global pelagic nitrogen denitrification. The low oxygen waters lie below the thermocline. There would then be more warm, higher oxygen water in the ETNP during warm periods. If the low oxygen waters impact the dolphin or their prey then conceivably the warm years would have positive effects. Data from the yellow fin tuna fishery seem to indicate that the yellow fin tuna favor the warm decades.

In conclusion, the available data strongly suggests that the carrying capacity of the dolphin habitat was significantly different before and after the mid seventies. Given that there is no data collected prior to 1975 one can only speculate as to which of the environments (pre or post 1975) was more favorable to the dolphins. The NOAA Fisheries data on dolphin prey abundances suggests that the environment is more favorable for the prey during the cool years. On the other hand there is circumstantial evidence from the yellow fin tuna that the environment for these organisms, that have an ecological association with the dolphins, was better during the warm decades. There are strong indications that a new change in the multi-decadal cycle may have occurred after the 1997-98 El Niño (Greene, 2002; Figure) and this raises the question of what will happen to the environment and the dolphin populations over the next decade. I would urge NOAA to repeat their studies in a few years to determine how the environment and the dolphins respond to the new regime. The data set collected to date is truly unique and should be continued. Data collected during the first half of the year when the upwelling

regions of Tehuantepec and Papagallo are prominent and El Niño is typically strongest would be extremely valuable.



Hypothetical oscillation of a regime index with a period of about 50 years. The early 1950s to about 1975 was when anchovies dominated the Pacific. The 1975 to late 1990s were when the sardine dominated. The spatial pattern of sea surface temperatures (SST) and atmospheric forcing is shown for each regime. Above the cool anchovy regime is the first empirical orthogonal function (EOF) of global TOPEX sea surface height (SSH) from 1993 to 2002, accounting for 31% of the variance in the time series. Input data were binned to 31 km along track and 30 days and were 18-month low-pass filtered. The coefficient of the global mode is shown together with chlorophyll for the eastern margin of the California Current system in Monterey Bay. Notice the changes after 1997-98.

## References

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